http://dx.doi.org/10.22161/ijeab/2.1.26 ISSN: 2456-1878

# Forms and Distribution of Potassium along a Toposequence on Basaltic Soils of Vom, Jos Plateau State of Nigeria

M. A. Tijjani *, A. A. David

Department of Soil Science, Allahabad School of Agriculture, Sam Higginbottom University of Agriculture, Technology & Sciences, Allahabad, 211007 U.P. India.

***Abstract—*** *The study was conducted in Vom, Jos Plateau state in the Southern Guinea Savanna zone of Nigeria to accentuate the forms of potassium distribution associated with topographic positions. The study area lies between longitudes 08$^0$ 45' 01" and 8$^0$ 47' 56'' E, latitudes 9$^0$ 43' 17'' and 9$^0$ 45' 15'' N, with an elevation of about 1270m above sea level. A stratified purposive sampling procedure was adapted, where four landscape positions were identified using Global Positioning System (GPS). The crest, upper slope, middle, and lower slope positions were identified, each representing changes in geomorphology. Two pedons were georeferenced at each topographic position, where they were sunk and described. Result show that the forms of K varied with topographic positions. Potassium distribution varied from surface to subsurface in different topographic positions. Water soluble K was higher at crest surface (0.0569 cmolkg$^{-1}$) and decreased with soil profile depth. Exchangeable K has highest value of 0.1317 and 0.1308 cmol/kg$^{-1}$ at both lower slope positions in general. Non exchangeable K values where higher at all surfaces than the subsurfaces of topographic positions. HCl soluble K values were higher at lower and upper slopes surface, moderately at middle and least at crest slope positions. Total K values were higher at upper slope subsurface, middle, and lower slope surface with low variations at the crest positions. However, the distribution of the K forms did not shown a well – defined trend with respect to topographic positions.*

***Keywords—* *Potassium forms, topographic positions, Basaltic soil***

## I. INTRODUCTION

Potassium is the major nutrient and also a most abundant element in soils but the K content of the soil varies from place to place based on physicochemical properties of soil **(Lalitha and Dhakshinamoorthy 2013)**. It plays significant roles in translocation of photosynthates, imparting vigour to plants, stimulating the growth of legumes, increasing the availability of other elements like nitrogen and potash **(Sahai, 2011; Lakudzala, 2013)**. Soil potassium exists in four forms: solution, exchangeable, non-exchangeable, and total K **(Al-Zubaidi *et al*. 2011)**. The distribution of K forms differs with the soil depth and space depending on some overriding environmental and soil factors **(Reza *et al*. 2013)**. These forms, however, are in dynamic equilibrium with one another and change from one form to another. Exchangeable K, is held through electrostatic charges present on organic matter and on clay particles, non-exchangeable constitutes the fraction held between adjacent tetrahedral layers of dioctahedral and trioctahedral micas, vermiculite and intergrade minerals that is sparingly or moderately available to plants while mineral K as a portion of total K is present in such K-bearing minerals as muscovite, biotite, feldspars, microcline and orthoclase **(Conyers and Mc Clean, 1967; Sadusky *et al*. 1987; (Sparks, 2000); Uzoho and Ekeh 2014; (Uzoho et al. 2016).**

Topography generally modifies the development of soil in pedogenesis as a result of microclimate and drainage **(Pidwirny, 2006)**. It is a factor that causes properties differentiation along hillslope and among horizons thereby evaluating the interaction of pedogenic and geomorphic processes **(Gessler *et al*. 2000)**. The Soil formation, mineral weathering, geomorphological conditions have resulted in significant variation in total, non-exchangeable and exchangeable K along different topographic slope positions **(Rezapour *et al*. 2010); Samndi and Tijjani, 2014)**. Variations in slope positions, soil depth and clay mineralogy are some aspect of soil K distribution **(Koné *et al*. 2014)**. The soil at the crest and upper slope position has higher pH values compared to the lower slope position **(Sohotden *et al*. 2015)**. While on the other hand,

significantly higher surface pH values on the foot slope were recorded, moreover the acidic pH might be due to the effect of erosion and leaching of nutrients down the slope **(Tsui *et al*. 2004)**.

In Nigeria, **Obi *et al*. (2016)** studied the effect of land use on soil K forms reported that the amount of total K, non-exchangeable K, exchangeable K and water soluble K as well as pH differed along topographic positions from up to middle to lower positions. **Osodeke *et al*. (2014)** reported a strong relationship between topographic positions on Coastal Plain Sand parent material in Amaeba-Imo Area of Southeastern Nigeria, however this relationship with respect to basaltic parent materials of Vom Jos Plateau, particularly with respect to potassium distribution and its interrelationship has not been adequately published for sustaining crop production, particularly, root and tuber crops. This is because potassium imparts resistance to diseases and insects as well as drought tolerance **(Rehm and Schmitt, 2002).**

## II. MATERIALS AND METHODS

**Study Location:** The study location was Vom, Jos Plateau State situated between longitude $08^0$ 45' 01 to $8^0$ 47' 56E'' and latitude $9^0$ 43' 17 to $9^0$ 45' 15N, with an elevation of about 1270m above sea level. It has a mean annual rainfall of about 1258mm and temperature of $24^0$C. The soils of the study area were derived from Newer Basalts material with Ustic soil moisture and Iso hyperthermic temperature regime respectively **(Eswaran *et al*. 1997)**.

**Sample Collection and Preparation**: Geographic Position System was used to obtain the co-ordinates of the four topographic positions (crest, upper, middle and lower topographic positions) which were indentified and each representing geomorphologic variations among positions using stratified purposive sampling procedure. Two pedons were sunk and described by genetic horizons and was sampled for laboratory analysis.

Laboratory analysis: Soil pH was determined in water, using soil sample to water ratio of 1:5 and read with a glass electrode meter **(Blackmore *et al*. 1987)**. Water soluble K was determined by shaking 2g of soil with 10 mL of deionized water (1.5 w/v), after shaking for 30 minutes on mechanical shaker and later filtered to obtain clear extract according to **Jackson, (1973)**. Exchangeable K was measured by shaking 10g of soil sample in 1 M of $NH_4OAC$ (buffered at pH 7) followed by filtration. Non-exchangeable K was determined using 5.0g of soil sample boiled in 50 mL of 1 M $HNO_3$ solution and leached with 1 M $HNO_3$. The difference between K extracted through $HNO_3$ and exchangeable K was taken as non-exchangeable K as describe by **De Tunk *et al*. (1943)**. Hydrochloric acid soluble K was extracted with 1N HCl using soil-acid ratio of 1:10 **(Piper, 1950)**. Total K was measured by digesting 2g of soil samples with 20 mL of $HClO\text{-}HNO_3$ acid mixture and leached with HCl according to **Rayment and Lyon, (2011)**. Mineral K was calculated by subtracting total K from $HN0_3$ extractable. All K forms extract were analyzed using the flame photometer.

## III. RESULTS AND DISCUSSION

Soil pH values with respect to different topographic positions ranged between 5.7 and 7.5 (Table 1). Slightly higher mean value (7.0) was obtained on the crest positions, while for the other topographic positions, mean pH values varied from 6.1 to 6.3. The resultant lower soil pH variations might be due to moderately weathering of soil along the topographic positions. Similar narrow change in soil pH values with topographic positions was observed by **Sanaullah *et al.* (2016)**.

Mean values of soluble K from surface horizon were not significantly ($P > 0.05$) affected by different topographic slope positions (Table 1), however values were higher (0.0569 cmolkg$^{-1}$) on the crest position, this might be due to less runoff with little erosion at the surface than subsurface while the lowest (0.0187 cmolkg$^{-1}$) on lower topographic positions (Table 2). **Tsui *et al*. (2004)** reported that higher available K content on crest with slightly lower variability among different topographic positions. For the subsurface horizons, mean values were also not significant, although slightly higher mean (0.0345 cmolkg$^{-1}$) value was obtained on the middle topographic positions. Water soluble K distribution mean values were irregularly distributed for some profiles (Table 2). **Al-Zubaidi *et al*. (2011)** reported similar pattern of K distribution in some Lebanese soils.

The mean values of the exchangeable K in the overlaying horizons were also not statistically significant, though values were higher (0.1317 cmolkg$^{-1}$) on the upper topographic position, followed by the crest, lower, and middle topographic positions (Table 1). Morealso, the distribution of exchangeable K in the subsurface horizons were significant with respect to topographic positions. The lowest mean value obtained on the lower topographic position was (0.0860 cmolkg$^{-1}$) at middle slope lower than the highest mean (0.1308 cmolkg$^{-1}$) value at crest positions. **Rubio and Gill-Sotres, (1997)** reported that values of exchangeable K were lower at overlying horizons which might attributed to soil forming processes. Generally, values

http://dx.doi.org/10.22161/ijeab/2.1.26 ISSN: 2456-1878

of exchangeable K showed an irregular distribution with profile depth at both topographical slope positions.

The mean values of non exchangeable K were significantly affected by topographic positions for both surface and subsurface mean values (Table 1). However, the surface highest (0.7133 cmolkg$^{-1}$) and the lowest (0.2456 cmolkg$^{-1}$) mean values were recorded at both upper and crest position respectively, also with moderate (0.4461 and 0.5441 cmolkg$^{-1}$) mean values at both lower and middle topographic positions respectively. For the subsurface horizons, the highest (0.4060 cmolkg$^{-1}$) and the lowest (0.2136 cmolkg$^{-1}$) mean values were recorded on upper and crest topographic positions respectively. Meanwhile moderate (0.2424 and 0.3141 cmolkg$^{-1}$) mean values were recorded at both middle and lower topographic positions. The distribution of non-exchangeable K also showed an irregular trend with respect to various topographic positions. Generally, the values of non-exchangeable K were higher in surface horizons increased with soil depth across the different topographic positions (Table 3).

The distribution of HCl solution K was significantly affected by topographic positions for both surface and subsurface horizons. In the surface horizons, mean values of HCl soluble K values were higher on the lower topographic positions. The highest mean value (0.5601 cmolkg$^{-1}$) was recorded on the lower slope while the lowest (0.3315 cmolkg$^{-1}$) mean value was obtained on crest positions respectively. For the underlying horizons, highest and lowest mean values (0.5300 and 0.3428 cmolkg$^{-1}$) were both obtained on the middle and crest slope positions respectively. The distribution of both surface and subsurface HCl soluble K showed an irregular trend with increasing profile depth.

The surface distribution of total K was significantly affected by topographic positions. The highest and the lowest mean (1.0749 and 0.8306 cmolkg$^{-1}$) values were recorded at the middle and crest topographic positions respectively. Meanwhile for the underlying horizon, the highest and the lowest mean (1.2047 and 0.607 cmolkg$^{-1}$) value were also significantly at both upper and middle topographic positions respectively.

## IV. CONCLUSION

The soil pH showed an irregular distribution trends across the various topographic positions. The surface distribution of water soluble K values were higher (0.1374 cmolkg$^{-1}$) on crest followed by middle, upper and least at the upper topographic positions. For the underlying horizons, water soluble K was lower (0.0205 cmolkg$^{-1}$) at the crest. Likewise for the surface distribution of exchangeable K, mean values were not significantly affected with respect to topographic positions. However, mean higher values (0.1317 cmolkg$^{-1}$) were recorded on upper slope, followed by crest, lower and least at middle positions. The underlying surface horizons indicated that the values were significantly affected by different topographic positions with the highest (0.1109 cmolkg$^{-1}$) on the crest, followed by lower, middle and least at the upper slope. The values of the non exchangeable K for the surface and subsurface horizons were statistically significant, though higher values were obtained on surface than subsurface and irregularly distributed across the horizons irrespective of the topographic positions. The HCl soluble K distribution was significantly influence by the various topographic position for both surface and subsurface horizons. The lowest (0.3315 and 0.3428 cmolkg$^{-1}$) mean values were obtained on both crests of the two horizons. The effect of topographic positions on total K distribution for the surface and subsurface horizons was statistically significant, with the lowest (0.8306 and 0.7060 cmolkg$^{-1}$) mean values obtained on the crest of the two horizons.

*Table.1: Mean forms of potassium distribution in surface and subsurface soils on various topographic positions of the study area.*

| | **Water soluble K** | **Exchangeable K** | **Non exchangeable K** | **HCl solution K** | **Total K** |
|---|---|---|---|---|---|
| **Variable** | | | **Cmolkg$^{-1}$** | | |
| **Surface topographic positions** | | | | | |
| **Crest** | 0.0569 | 0.1158 | 0.2456 | 0.3315 | 0.8306 |
| **Upper slope** | 0.0205 | 0.1317 | 0.7133 | 0.5068 | 0.8898 |
| **Middle slope** | 0.0276 | 0.1086 | 0.5441 | 0.4871 | 1.0749 |
| **Lower slope** | 0.0187 | 0.1122 | 0.4461 | 0.5601 | 1.0325 |

http://dx.doi.org/10.22161/ijeab/2.1.26 ISSN: 2456-1878

| | | | | | |
|---|---|---|---|---|---|
| **F- test** | NS | NS | S | S | S |
| **S. Ed. (±)** | 0.016 | 0.023 | 0.011 | 0.013 | 0.065 |
| **C. D. (P = 0.05)** | 0.034 | 0.049 | 0.022 | 0.027 | 0.138 |
| **Subsurface topographic positions** | | | | | |
| **Crest** | 0.0225 | 0.1109 | 0.2136 | 0.3428 | 0.7060 |
| **Upper slope** | 0.0241 | 0.0131 | 0.4060 | 0.4738 | 1.2047 |
| **Middle slope** | 0.0345 | 0.0860 | 0.2424 | 0.5300 | 0.6070 |
| **Lower slope** | 0.0205 | 0.0986 | 0.3141 | 0.3960 | 0.8746 |
| **F- test** | NS | S | S | S | S |
| **S. Ed. (±)** | 0.035 | 0.027 | 0.015 | 0.016 | 0.078 |
| **C. D. (P = 0.05)** | 0.074 | 0.058 | 0.032 | 0.034 | 0.164 |

*Table.2: Forms of potassium distribution in soil profiles on the crest, upper, middle and lower topographic positions in the study area.*

| **Horizon** | **Depth (cm)** | **pH** | **Water Soluble K (cmolkg$^{-1}$)** | **Exchangeable K (cmolkg$^{-1}$)** | **Non Exchangeable K (cmolkg$^{-1}$)** | **HCl soluble K (cmo/kg$^{-1}$)** | **Total K (cmolkg$^{-1}$)** |
|---|---|---|---|---|---|---|---|
| **Crest profile 1** | | | | | | | |
| A | 0-14 | 6.5 | 0.0605 | 0.0997 | 0.3526 | 0.3101 | 1.2581 |
| Bt1 | 14-29 | 6.4 | 0.0305 | 0.0641 | 0.2403 | 0.3541 | 0.5453 |
| Bt2 | 39-73 | 7.3 | 0.0303 | 0.0713 | 0.5040 | 0.3471 | 0.4034 |
| Bt3 | 73-120 | 6.9 | 0.0232 | 0.0749 | 0.2009 | 0.3219 | 0.9966 |
| BC | 120-143 | 7.2 | 0.0142 | 0.0677 | 0.1673 | 0.3242 | 0.7590 |
| **Crest profile 2** | | | | | | | |
| A | 0-16 | 7.1 | 0.2140 | 0.1318 | 0.1385 | 0.3169 | 0.4034 |
| AB | 16-59 | 6.9 | 0.0160 | 0.2352 | 0.0621 | 0.2688 | 0.7368 |
| Bt1 | 59-94 | 7.0 | 0.0142 | 0.0818 | 0.2317 | 0.2173 | 0.8068 |
| Bt2 | 94-137 | 7.3 | 0.0214 | 0.0749 | 0.2223 | 0.6442 | 0.7829 |
| BC | 137-180 | 7.5 | 0.0305 | 0.2172 | 0.0800 | 0.2651 | 0.6171 |
| **Upper slope profile 1** | | | | | | | |
| A | 0-10 | 6.4 | 0.0232 | 0.1815 | 0.4579 | 0.3794 | 0.5932 |
| AC | 10-50 | 6.1 | 0.0214 | 0.0818 | 0.4240 | 0.4240 | 1.0923 |
| Cr | 50-130 | 6.1 | 0.0303 | 0.1282 | 0.2118 | 0.5041 | 1.2342 |
| **Upper slope profile 2** | | | | | | | |
| A | 0-14 | 6.3 | 0.0178 | 0.0818 | 0.9686 | 0.6342 | 1.1863 |
| AC | 14-39 | 6.0 | 0.0285 | 0.0749 | 0.3453 | 0.5022 | 1.4239 |
| Cr | 39-125 | 6.5 | 0.0160 | 0.2387 | 0.6427 | 0.4648 | 1.0684 |
| **Middle slope profile 1** | | | | | | | |
| A | 0-29 | 6.1 | 0.0356 | 0.0926 | 0.4487 | 0.4133 | 1.4947 |
| B | 29-80 | 6.0 | 0.0249 | 0.0713 | 0.1746 | 0.4133 | 0.9504 |

http://dx.doi.org/10.22161/ijeab/2.1.26 ISSN: 2456-1878

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bt1 | 80-122 | 6.1 | 0.0303 | 0.0356 | 0.3828 | 0.5608 | 0.1658 |
| Bt2 | 122-147 | 6.0 | 0.1060 | 0.0641 | 0.1835 | 0.3973 | 0.9265 |
| Cr | 147-185 | 6.2 | 0.0249 | 0.1567 | 0.1389 | 0.3169 | 0.4752 |
| **Middle slope profile 2** | | | | | | | |
| A | 0-31 | 6.6 | 0.0196 | 0.1246 | 0.6394 | 0.5609 | 0.6550 |
| AC | 31-62 | 6.1 | 0.0178 | 0.0749 | 0.3135 | 0.5483 | 0.8068 |
| Cr1 | 62-123 | 6.3 | 0.0106 | 0.0785 | 0.2812 | 0.5519 | 0.4752 |
| Cr2 | 123-167 | 7.3 | 0.0267 | 0.1210 | 0.2226 | 0.3579 | 0.5453 |
| **Lower slope profile 1** | | | | | | | |
| A | 0-28 | 6.4 | 0.0232 | 0.1354 | 0.7035 | 0.5537 | 1.2581 |
| Bt1 | 28-77 | 5.7 | 0.016 | 0.0641 | 0.4537 | 0.4040 | 0.7128 |
| Bt2 | 77-135 | 5.7 | 0.0142 | 0.0785 | 0.3063 | 0.3986 | 1.2103 |
| Cr | 135+ | 5.7 | 0.0196 | 0.0713 | 0.066 | 0.2794 | 0.9966 |
| **Lower slope profile 2** | | | | | | | |
| A | 0-22 | 6.3 | 0.0142 | 0.0890 | 0.1886 | 0.5665 | 0.8068 |
| B | 22-64 | 6.1 | 0.0214 | 0.0641 | 0.2848 | 0.6124 | 1.0923 |
| BC | 64-93 | 6.1 | 0.0305 | 0.0785 | 0.2541 | 0.4325 | 0.7366 |
| Cr | 93+ | 7.1 | 0.0214 | 0.2352 | 0.5198 | 0.2490 | 0.4991 |

*Table.3: Mean values of surface and subsuface forms of potassium distribution in soil profiles on the various topographic positions in the study area.*

| Horizon | Water soluble K ($cmolkg^{-1}$) | Exchangeable K ($cmolkg^{-1}$) | Non exchangeable K ($cmolkg^{-1}$) | HCl Soluble K ($cmolkg^{-1}$) | Total K ($cmolkg^{-1}$) |
|---|---|---|---|---|---|
| **CREST PROFILE** | | | | | |
| surface | 0.0569 | 0.1158 | 0.2456 | 0.3135 | 0.8380 |
| subsurface | 0.0225 | 0.1109 | 0.2136 | 0.3428 | 0.7070 |
| **UPPER SLOPE** | | | | | |
| surface | 0.0205 | 0.1317 | 0.7133 | 0.5068 | 0.8898 |
| subsurface | 0.0241 | 0.1308 | 0.4060 | 0.4870 | 1.2047 |
| **MIDDLE SLOPE** | | | | | |
| surface | 0.0276 | 0.1086 | 0.5441 | 0.4871 | 1.0749 |
| subsurface | 0.0345 | 0.0860 | 0.2424 | 0.5300 | 0.6207 |
| **LOWER SLOPE** | | | | | |
| surface | 0.0187 | 0.1122 | 0.4461 | 0.5601 | 1.0325 |
| subsurface | 0.0205 | 0.0986 | 0.3141 | 0.3960 | 0.8746 |

## REFERENCES

[1] Al-Zubaidi, A., Bashour, I., Darwish, T. and Safieddine, M. (2011). *Content of Different Forms of Potassium in Lebanese Soils.* Switzerland: International potash Institute.

[2] Blackmore, L. C., Searle, P. L. and Daly, B. K. (1987). Method for Chemical Analysis of Soil. *New Zealand Soil Bureau Scientific Report* , 103.

[3] Conyer, E. and Mclean, L. (1969). Plant Uptake and Chemical Extractions for Evaluating Potassium Release Characteristics of Soil. *Soil Sci. Am. Proc* , 226-230.

[4] De Tunk, E. E., Wood, L. K. and Bray, R. H. (1943). Potassium fixation in corn belt soils. *Soil Science* , 1-12.

[5] Eswaran, H., Almaraz, R., van den Berg, E. and Reich, P. (1997). An assessment of soil resources of Africa in relation to productivity. *Geoderma* , 1-18.

[6] Gessler, P. E., Chamran, F., Althouse, L. and Holmes, K. (2000). Modelling soil-landscape and ecosystem properties using terrain attributes. *Soil Science Society of America* , 2046-2056.

[7] Jackson, M. L. (1973). *Soil Chemical Analysis.* new Delhi: Prentice Hall of India, Private Limited.

[8] Koné, B., Bongoua-Devisme, A. J., Hippolyte, K. K., Firmin, K. K. and Joachim, T. M. (2014). Potassium supplying capacity as indicated by soil colour in Ferralsol environment. *Basic Research Journal of Soil and Environmental Science* , 46-55.

[9] Lakudzala, D. D. (2013). Potassium responce in some Malawi soils. *Internatonal Letters of Chemistry, Physics and Astronomy* , 175-181.

[10] Lalitha, M. and Dhakshinamoorthy, M. (2013). Forms Of Soil Potassium- A Review. *Agri. Reviews* , 64-68.

[11] Obi, J. C., Ibia, T. O. and Eshiet, P. B. (2016). Effect of land use on potassium forms of coastal plain sands of Nigeria. *Chemistry and Ecology* , 1-21.

[12] Osodeke, V. E., Akinmutimi, A. L. and Inyama, C. (2014). Potassium Distribution along a Toposequence of Coastal Plain Sand Parent Material in Amaoba-Ime Area of Southeastern Nigeria. *Nigerian Journal of Soil Science and Environmental Research* , 1-9.

[13] Pidwirny, M. (2006). *"Soil Pedogenesis".Fundamentals of Physical Geography.* Okanagan: Scott Jones University of British Columbia.

[14] Piper, C. S. (1950). *Soil and Plant Analysis.* New York: Inter Science Publishers.

[15] Rayment, G. E. and Lyon, D. L. (2011). *Soil Chemical Method.* Australia: Csiro Publishing.

[16] Rehm, G. and Schmitt, M. (2002). *Potassium for crop production.* Minnesota USA: Regents of the University of Minnesota.

[17] Reza, S. K., Utpal, B., Chattopadhay, T. and Dipak, S. (2013). Distribution of forms of potassium in relation to different different agroecological regions of North-Eastern India. *Archives of Agronomy and Soil Science* , 507-518.

[18] Rezapour, S. A., Samadi, A. A., Jafarzadeh, S. and Oustan, S. (2010). Impact of Clay Mineralogy and Landscape on Potassium Forms in Calcareous Soils, Urmia Region. *Journal Agr. Sci. Tech.* , *12*, 495-507.

[19] Rubio, B., and Gill-Sotres, F. (1997). Distribution of four major forms of potassium in soils of Galicia (N.W. Spain). *Communications in Soil Science and Plant Analysis* , 1805-1816.

[20] Sadusky, M. C., Sparks, D. L., Noll, M. R. and Hendricks, G. J. (1987). Kinetics and mechanisms of potassium release from sandy soils. *Soil Science Society of America Journal* , 1460-1465.

[21] Sahai, V. N. (2011). *Fundamentals of Soil* . New Delhi: Kalyani Printings.

[22] Samndi, M. A. and Tijjani, M. A. (2014). Distribution of Potassium Forms along a Hillslope Positions of Newer Basalt on the Jos Plateau Nigeria. *International Journal of Soil Science* , 90-100.

[23] Sanaullah, A. F., Akhtaruzzaman, M. and Uddin, M. A. (2016). Effect of Topography and Soil Depth on Clay Content, Organic Matter Content, Active Acidity, Reserve Acidity and Cation Exchange Capacity of Some Tea Soils of Bangladesh. *Journal of Scientific Research* , 229-235.

[24] Sohotden, C. D., Vivan, E. L., Ali, A. Y. and Shehu, B. M. (2015). An Assessment Of Landscape Segments Suitability For Agriculture in Kwrang Volcanic Area Of Jos Plateau, Nigeria. *International Journal of Scientific and Technology Research* , 294-297.

[25] Sparks, D. L. (2000). *Bioavailability of soil potassium, D-38-D-52. In M.E. Sumner (ed.).* Florida: Handbook of Soil Science, CRC Press, Boca Raton.

[26] Tsui, C. C., Chen, Z. S. and Hsieh, C. F. (2004). Relationship between soil properties and slope position in a lowland rain forest of southern Taiwan. *Geoderma* , 131-142.

[27] Uzoho, B. U. and Ekeh, C. (2014). Potassium status of soils in relation to land use types in Ngor- Okpala, Souteastern, Nigeria. *Journal of Natural Sciences Research* , 104-114.

[28] Uzoho, B. U., Ihem, E. E., Ogueri, E. I., Igwe, C. A., Effiong, J. A. and Njoku, G. U. (2016). Potassium Forms in Particle Size Fractions of Soils on Toposequence in Mbano, Southeastern Nigeria. *International Journal of Environment and Pollution Research* , 1-11.